The SJSATBPC package : mainframe-quality results with the Crash Victim Simulation in the microcomputer environment

Dr. Saami J. Shaibani *

512 N. Kensington St., Arlington, VA 22205

Presented at Seventeenth International Workshop
on Human Subjects for Biomechanical Research,
Washington, DC, October 4, 1989

Abstract

The author of the original validated minicomputer version of the Crash Victim Simulation (CVS) has now produced a microcomputer version, known as the SJSATBPC package, which gives mainframe-quality results. The main part of the package is the SJSCVSPC program and this is enhanced by the companion program SJSVUEPC, which displays on a microcomputer the pictures generated within CVS. The executable images of both programs run independently of hardware configuration and their accuracy has been verified by a detailed series of comparisons with outputs from mainframe computers and minicomputers. In all cases, even in the most complicated simulations, total agreement was obtained. Thus, mainframe-quality results may now be achieved with CVS without the high cost, long turnaround time, difficulty of access or lack of availability usually associated with mainframe computers.

1. Introduction

The Crash Victim Simulation (CVS) program is a computer program which models the response of a multi-segmented body to an impact, or other insult, in geometrically definable surroundings. Typically, the body is an anthropomorphic test device or "dummy", the insult is a passenger vehicle crash pulse and the surroundings are a passenger vehicle compartment. The program was developed at the Calspan Corporation, Buffalo, NY, in the 1970s for use on mainframe computers and, as such, it was primarily a tool for advanced research [1-10]**. This limited status was transformed in the early 1980s when CVS was first adapted successfully for use in the minicomputer environment at the University of Oxford, England, where major progress was made in expanding the accessibility of CVS [11-17].

* Present address : Chi Associates, Inc.
** Numbers in brackets denote references at the end of the paper.

The work performed in Oxford represented an enormous breakthrough because the greater availability of CVS allowed it to be invoked on a regular basis, so complementing other analytical techniques. The most significant application of this newly found freedom with CVS was the ability to reconstruct in extensive detail some of the real-world accidents [15-17], which had been investigated on-scene to provide both engineering and clinical data. The consequent identification of injury mechanisms, and of related passenger vehicle compartment design issues, was a substantial novel contribution to the understanding of the physical causes of trauma.

The CVS program is closely related to the Articulated Total Body (ATB) program, and both programs are viewed as elite members of a family of programs which simulate occupant response in an impact event. Examples of other programs in this family include MVMA-2D and Madymo [18]. The latter has already been adapted for a microcomputer, firstly in its two-dimensional form and more recently in its three-dimensional form. (It should be noted that all references to CVS here involve the three-dimensional case.)

Although Madymo enjoys the convenience of microcomputer application, it is generally accepted as not being as powerful or as descriptive, or as sophisticated, as CVS. It is these shortcomings of Madymo that has heightened the interest in developing a <u>reliable</u> version of CVS for a microcomputer. Previous attempts at putting CVS on a microcomputer must be considered inadequate either because the version was hardware-dependent or because it did not give results similar to a mainframe computer or a minicomputer. However, the research reported here does give mainframe-quality results and so represents the definitive product that has been sought after for such a long time.

2. Technical details

Early versions of the CVS Fortran IV source code contained some 12,000 lines distributed over more than 100 subprograms (subroutines and functions). These figures have increased to nearly 15,000 lines with the addition of the extra facilities found in the 120 or so subprograms of later versions. All versions of CVS require anything from 200 to 500 lines of input data for a typical automotive simulation. Each line of data in CVS applications is still commonly called a "card" even though the 7.375-inch (width) by 3.25-inch (length) punched card to which it refers is rarely seen any more.

These punched cards were the only readily viable media for introducing program and data material to the mainframe computers, which were in use at the outset of the development of CVS. An assembly of punched cards was called a "deck", so that what is now known as a data file was then known as an input deck. The standard format for a CVS input deck is divided into the 9 categories shown in Table 1.

The SJSCVSPC program has approximately 13,500 lines of Fortran, which occupy about 1.1 megabytes of disk storage, and it is derived from the original validated minicomputer version of CVS. The latter, in its turn, was based on the only other previous format used, namely that for mainframe computers. The minicomputer employed for this work at the

TABLE 1

Input deck for the Crash Victim Simulation

Cards	Description
A	start-up
B	dummy
C	crash pulse
D	vehicle geometry
E	vehicle properties
F	allowed contacts
G	seating position
H	tabular output
I	graphical output

University of Oxford was a Vax 11/780, and the final minicomputer program corresponded to version 20A of the mainframe computer source code.

The constraints of space do not allow an exhaustive account of the changes that were made to produce the SJSCVSPC program. Suffice it to say that the Fortran source code had to be converted into the most standard form possible, unlike the irregular forms seen in the previous mainframe computer and minicomputer source codes. The latter source codes did not conform precisely with the official definitions of Fortran IV or Fortran 77, and they only worked because of the generous forgiving nature of the Fortran compilers on those types of computers. This flexibility afforded by large computers is not generally available in the more compact Fortran compilers to which microcomputers are limited.

The source code in SJSCVSPC was compiled with a 32-bit compiler on an IBM microcomputer with an Intel 80386 processor, which could be run optionally in conjunction with an Intel 80387 math coprocessor, under version 3 (or above) of the Microsoft disk operating system (DOS). A virtual memory capability was incorporated, but not necessarily invoked, to allow all aspects of the SJSATBPC package to be undertaken with <u>any</u> amount of random access memory (RAM). Not only does this have the advantage of giving a hardware-independent result but it also reduces cost by obviating the need for extra RAM which is very expensive. Furthermore, this approach has the additional benefit of not requiring the cumbersome use of overlay techniques that have been attempted elsewhere.

The object module of SJSCVSPC was linked into a remarkably small executable image of only 0.4 megabytes, which included linking with a Calcomp graphics library. The purpose of the latter was to emphasize the complete transportability and independence of SJSCVSPC because these attributes are viewed as being of paramount importance. It is unfortunate, to say the least, that this philosophy has not governed other efforts, which have restricted themselves to a single system or type of system. The inability to use these efforts in other systems undermines any validity which they may possess.

Yet other efforts must be viewed as suspect because they do not give the same results as those seen with mainframe computers or minicomputers. Another more recent approach may be unsatisfactory because it may have departed from the central theme of CVS to the extent that it may effectively represent a new program altogether.

A similar set of procedures to those which produced SJSCVSPC above was undertaken with the View program [19-20], leading here to the SJSVUEPC program. The latter takes one of the outputs from CVS as one of its two inputs and draws the pictures generated by CVS; the second input is a small control deck of only 15 or so cards. The View program has approximately 1,500 lines of Fortran IV source code distributed over about 30 subprograms, and thus it requires very little disk storage. The executable image of SJSVUEPC is less than 0.1 megabytes, including the linking with a Calcomp graphics library. The combination of the SJSCVSPC and SJSVUEPC programs, and the related input/output control parameters, constitute the SJSATBPC package developed during this research.

3. Results

There are three types of hard-copy results which the SJSATBPC package produces -- tables, graphs and pictures. The first two of these are from the SJSCVSPC program and the last is from the SJSVUEPC program. Each is covered below in a separate section, in which the values obtained from SJSATBPC are compared directly with those seen in the same simulations performed on minicomputers. For the sake of brevity, the actual examples presented here are only a small subset of all the work performed and they do not include the results produced by two different IBM mainframe computers with the same data.

In addition to the comparisons for the coincidence of numerical values, approximate comparisons were made of the run times on each type of computer. The latter comparisons had to be qualitative because different input data gave a range of different durations. However, as a general rule, run times for the SJSCVSPC program with the microcomputer equipment described in the previous section were usually less than those for CVS on a Vax 11/780 minicomputer. By definition, such a value for relative performance can vary enormously because it depends on the workload of the latter from other users' demands.

3.1 Tabular output

The modeling of the response of a front seat passenger in a particular real-world road traffic accident has already been explained in some detail by the author during the work he performed at the University of Oxford [15]. The human occupant in this real-world accident was simulated by two types of dummy -- a non-Euler Part572 and an Euler Part572 -- in separate executions of CVS on a Vax 11/780 minicomputer.

The equilibrium seating positions at the initial time t = 0 were described for the above dummies by the values of angular and linear acceleration given in reference [15], shown here in Tables 2(a) and 3(a). The abbreviations for the segments are : LT, CT, UT - lower torso, center torso, upper torso; N - neck; head - H; RUL (LUL), RLL (LLL), RF (LF) - right (left) upper leg, lower leg, foot; RUA (LUA), RLA (LLA) - right (left) upper arm, lower arm. Excellent equilibrium was achieved in both cases, thus eliminating the distinct possibility of spurious, artefactual results. The latter are known to arise even when the dummy has initial components of linear acceleration of "only" 0.5 g, where g is the acceleration of free fall under the influence of gravity at the surface of the earth.

The executions of SJSCVSPC with the same input data on an IBM microcomputer produced the values contained in Tables 2(b) and 3(b), which agree completely with Tables 2(a) and 3(a). (It should be noted that, whereas the agreement in Table 3 is exact, there are minimal truncation or rounding errors in just a few of the last of the six decimal places in Table 2.) This provides the first of many confirmations of the SJSATBPC package in the microcomputer environment giving the same results as CVS on a minicomputer. The input deck for the non-Euler Part572 dummy in Table 2 is labeled N2CCG001, in accordance with the scheme of nomenclature outlined in the Appendix. The fourth and fifth characters designate <u>C</u>itroen (make) and <u>G</u>S (model),

TABLE 2

Equilibrium values at time t = 0
for the input deck N2CCG001

(a) CVS on a minicomputer (taken from reference [15])

(b) SJSATBPC on a microcomputer

SEGMENT	(a) ANGULAR ACCELERATION (RAD/ SEC**2) X	Y	Z	(b) ANGULAR ACCELERATION (RAD/ SEC**2) X	Y	Z
1 LT	0.000000	0.065251	0.000000	0.000000	0.065252	0.000000
2 CT	0.000000	0.065251	0.000000	0.000000	0.065252	0.000000
3 UT	0.000000	0.065251	0.000000	0.000000	0.065252	0.000000
4 N	0.000000	0.065251	0.000000	0.000000	0.065252	0.000000
5 H	0.000000	0.065251	0.000000	0.000000	0.065252	0.000000
6 RUL	0.000000	-0.022619	0.000000	0.000000	-0.022612	0.000000
7 RLL	0.000000	0.079555	0.000000	0.000000	0.079554	0.000000
8 RF	0.000000	0.079555	0.000000	0.000000	0.079554	0.000000
9 LUL	0.000000	-0.022619	0.000000	0.000000	-0.022612	0.000000
10 LLL	0.000000	0.079555	0.000000	0.000000	0.079554	0.000000
11 LF	0.000000	0.079555	0.000000	0.000000	0.079554	0.000000
12 RUA	0.000000	0.065251	0.000000	0.000000	0.065252	0.000000
13 RLA	0.000000	0.065251	0.000000	0.000000	0.065252	0.000000
14 LUA	0.000000	0.065251	0.000000	0.000000	0.065252	0.000000
15 LLA	0.000000	0.065251	0.000000	0.000000	0.065252	0.000000
16 VEH	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

SEGMENT	(a) LINEAR ACCELERATIONS (G'S) X	Y	Z	(b) LINEAR ACCELERATIONS (G'S) X	Y	Z
1 LT	-0.000768	0.000000	0.000085	-0.000768	0.000000	0.000085
2 CT	-0.001429	0.000000	0.000685	-0.001429	0.000000	0.000685
3 UT	-0.002929	0.000000	0.000913	-0.002929	0.000000	0.000913
4 N	-0.004424	0.000000	0.001110	-0.004424	0.000000	0.001110
5 H	-0.005024	0.000000	0.001133	-0.005024	0.000000	0.001134
6 RUL	-0.000545	0.000000	0.000566	-0.000545	0.000000	0.000566
7 RLL	0.000483	0.000000	-0.000371	0.000483	0.000000	-0.000371
8 RF	0.001557	0.000000	-0.002303	0.001557	0.000000	-0.002303
9 LUL	-0.000545	0.000000	0.000566	-0.000545	0.000000	0.000566
10 LLL	0.000483	0.000000	-0.000371	0.000483	0.000000	-0.000371
11 LF	0.001557	0.000000	-0.002303	0.001557	0.000000	-0.002303
12 RUA	-0.002712	0.000000	0.000834	-0.002712	0.000000	0.000834
13 RLA	-0.001743	0.000000	-0.000643	-0.001743	0.000000	-0.000642
14 LUA	-0.002712	0.000000	0.000834	-0.002712	0.000000	0.000834
15 LLA	-0.001743	0.000000	-0.000643	-0.001743	0.000000	-0.000642
16 VEH	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

TABLE 3

Equilibrium values at time t = 0
for the input deck E2CCG001

(a) CVS on a minicomputer (taken from reference [15])

(b) SJSATBPC on a microcomputer

SEGMENT	(a) ANGULAR ACCELERATION (RAD/ SEC**2) X	Y	Z	(b) ANGULAR ACCELERATION (RAD/ SEC**2) X	Y	Z
1 LT	0.000000	1.071933	0.000000	0.000000	1.071933	0.000000
2 CT	0.000000	1.071933	0.000000	0.000000	1.071933	0.000000
3 UT	0.000000	1.071933	0.000000	0.000000	1.071933	0.000000
4 NECK	0.000000	1.071933	0.000000	0.000000	1.071933	0.000000
5 HEAD	0.000000	1.071933	0.000000	0.000000	1.071933	0.000000
6 LUL	0.000000	1.071933	0.000000	0.000000	1.071933	0.000000
7 LLL	0.000000	-0.474306	0.000000	0.000000	-0.474306	0.000000
8 LF	0.000000	-0.474306	0.000000	0.000000	-0.474306	0.000000
9 RUL	0.000000	1.071933	0.000000	0.000000	1.071933	0.000000
10 RLL	0.000000	-0.474306	0.000000	0.000000	-0.474306	0.000000
11 RF	0.000000	-0.474306	0.000000	0.000000	-0.474306	0.000000
12 LUA	0.000000	1.050339	-0.214076	0.000000	1.050339	-0.214076
13 LLA	0.000000	1.071933	0.000000	0.000000	1.071933	0.000000
14 RUA	0.000000	1.050339	0.214076	0.000000	1.050339	0.214076
15 RLA	0.000000	1.071933	0.000000	0.000000	1.071933	0.000000
16 VEH	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

SEGMENT	(a) LINEAR ACCELERATIONS (G'S) X	Y	Z	(b) LINEAR ACCELERATIONS (G'S) X	Y	Z
1 LT	0.049240	0.000000	0.075713	0.049240	0.000000	0.075713
2 CT	0.039722	0.000000	0.084143	0.039722	0.000000	0.084143
3 UT	0.015337	0.000000	0.089002	0.015337	0.000000	0.089002
4 NECK	-0.009430	0.000000	0.090656	-0.009430	0.000000	0.090656
5 HEAD	-0.019356	0.000000	0.089629	-0.019356	0.000000	0.089629
6 LUL	0.052940	0.000000	0.049324	0.052940	0.000000	0.049324
7 LLL	0.044570	0.000000	0.038320	0.044570	0.000000	0.038320
8 LF	0.037710	0.000000	0.050226	0.037710	0.000000	0.050226
9 RUL	0.052940	0.000000	0.049324	0.052940	0.000000	0.049324
10 RLL	0.044570	0.000000	0.038320	0.044570	0.000000	0.038320
11 RF	0.037710	0.000000	0.050226	0.037710	0.000000	0.050226
12 LUA	0.018335	0.000000	0.088252	0.018335	0.000000	0.088252
13 LLA	0.032594	0.000000	0.065200	0.032594	0.000000	0.065200
14 RUA	0.018335	0.000000	0.088252	0.018335	0.000000	0.088252
15 RLA	0.032594	0.000000	0.065200	0.032594	0.000000	0.065200
16 VEH	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

respectively, and the meaning of the other characters is included in Table A.1 of the Appendix. Similarly, the input deck for the Euler Part572 dummy in Table 3 is labeled E2CCG001.

3.2 Graphical output

A helpful feature provided within CVS is the facility for looking at its wide variety of outputs as a series of xy plots instead of the somewhat bulky tabular information, which is supplied as the default. This applies inter alia to the time histories for the angular, and linear, displacements, velocities and accelerations of the segments, and the contact forces between the segments and the vehicle panels (as controlled by the F cards -- see Table 1).

The modeling of the response of a driver in a different type of real-world road traffic accident from that referred to in the previous sub-section has also been undertaken by the author. Full details of this appear in the work performed at the University of Oxford [16-17]. The input data for the non-Euler Part572 and the Euler Part572 dummies in that study can be labeled N4BMS001 and E4BMS001, respectively, where the fourth character represents a British Leyland Marina and the fifth indicates the presence of a steering wheel. Again, all other characters are defined in Table A.1 of the Appendix.

Separate executions of CVS on a Vax 11/780 minicomputer generated the resultant linear acceleration of the upper torso for each dummy employed in the simulation of the driver in the above accident. These are depicted as a function of time in reference [16], and they are illustrated here as Figures 1(a) and 2(a) along with the corresponding graphs obtained with SJSATBPC in Figures 1(b) and 2(b).

The change in speed associated with the accident was in excess of 40 miles per hour, which indicates that the injury-inducing impacts all occurred within the first 100 or so milliseconds and that results after about 150 milliseconds are not usually considered to be meaningful. Thus, the major features of interest are those near 80, 90 and 110 milliseconds, and the overall structure of the graphs at these events shows good correspondence. Similarly high quality of matching is evidenced in Figures 3 and 4, which relate to the resultant linear acceleration of the head in the same accident. (It is believed that any discrepancies may be caused by transcription errors in the generation of current data from the original data obtained several years ago. Some examples of the sources of such errors are discussed at the end of the next sub-section.)

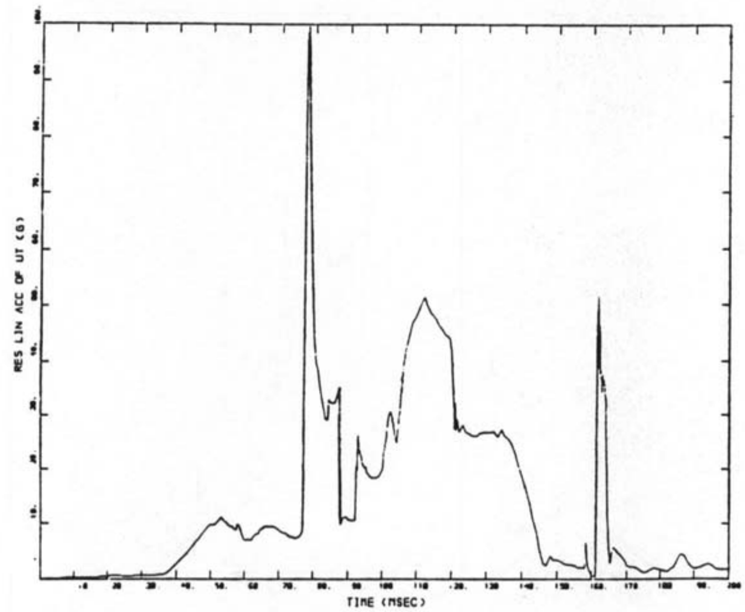
3.3 Pictorial output

The pictures produced by the View program on a Vax 11/780 minicomputer with the four input decks encountered in the two previous sub-sections are presented in references [15-17] as sequences of 20 images at 10-millisecond intervals. The first picture in each of these sequences applies to the initial time t = 0, and they are reproduced here as Figures 5(a), 6(a), 7(a) and 8(a). The output from running SJSVUEPC on an IBM microcomputer for the same input data is shown in Figures 5(b), 6(b), 7(b) and 8(b). The latter match the former

FIGURE 1

Time history of resultant linear acceleration
of upper torso with the input deck N4BMS001

(a) CVS on a minicomputer (taken from reference [16])



(b) SJSATBPC on a microcomputer

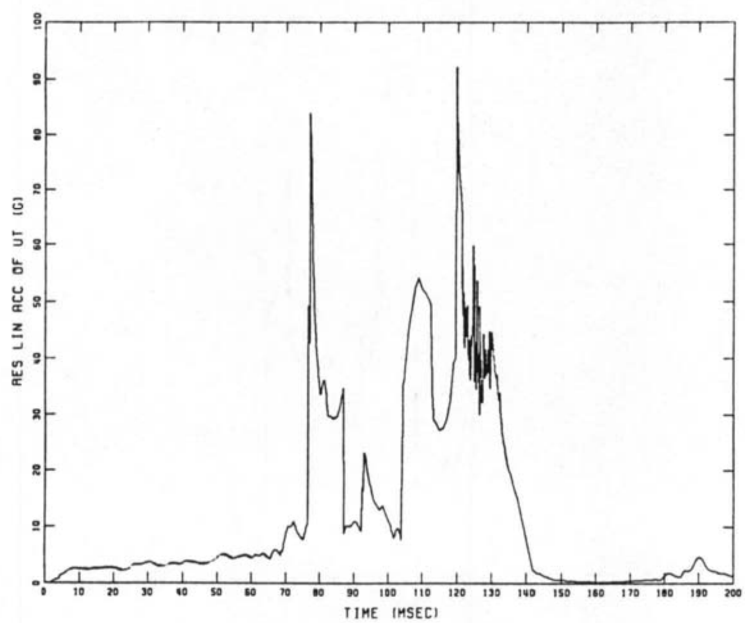
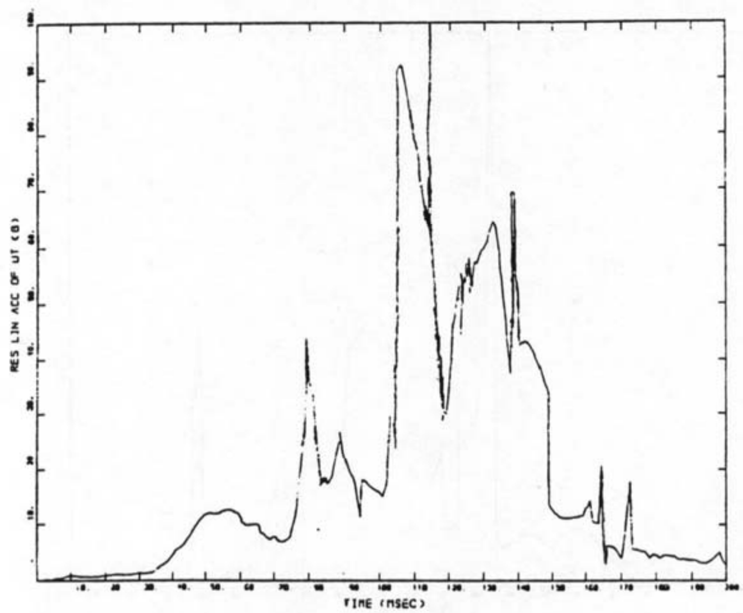


FIGURE 2

Time history of resultant linear acceleration of upper torso with the input deck E4BMS001

(a) CVS on a minicomputer (taken from reference [16])



(b) SJSATBPC on a microcomputer

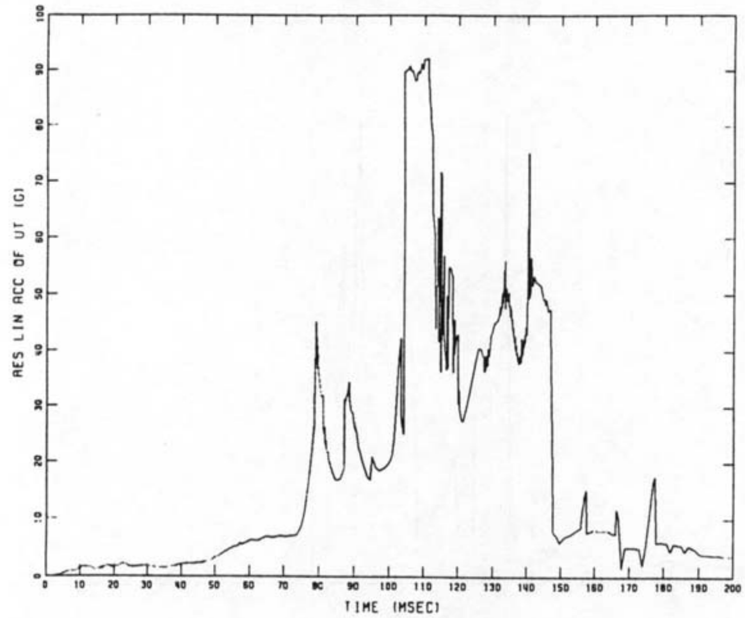
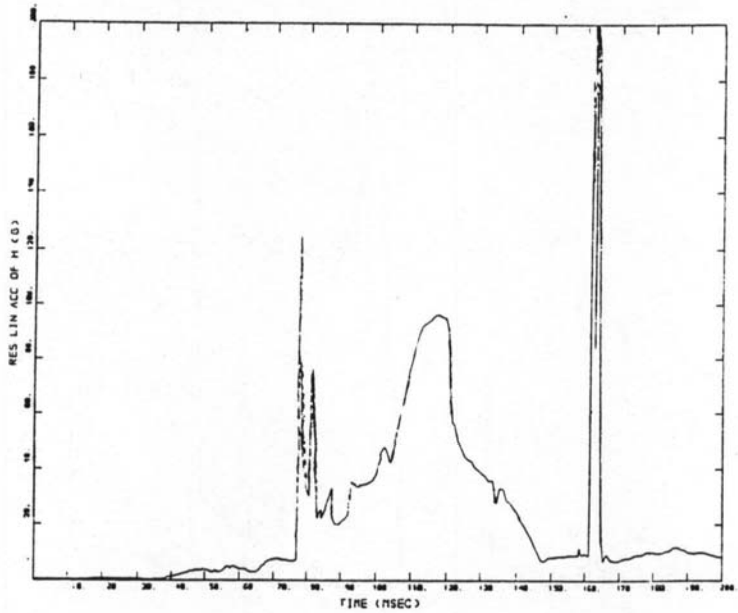


FIGURE 3

Time history of resultant linear acceleration of head with the input deck N4BMS001

(a) CVS on a minicomputer (taken from reference [16])



(b) SJSATBPC on a microcomputer

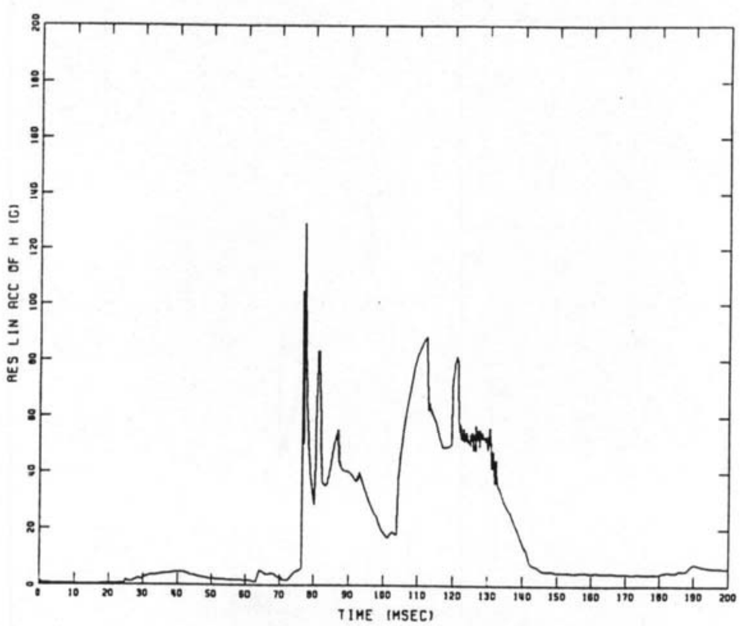
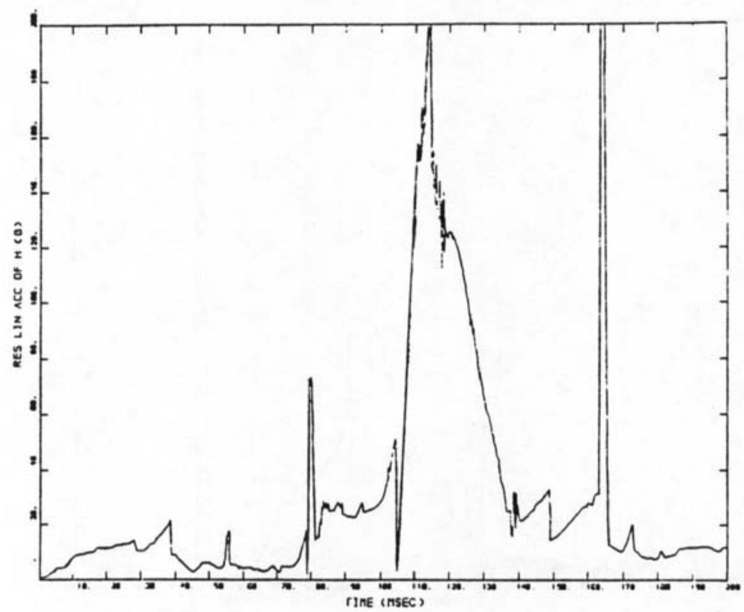


FIGURE 4

Time history of resultant linear acceleration
of head with the input deck E4BMS001

(a) CVS on a minicomputer (taken from reference [16])



(b) SJSATBPC on a microcomputer

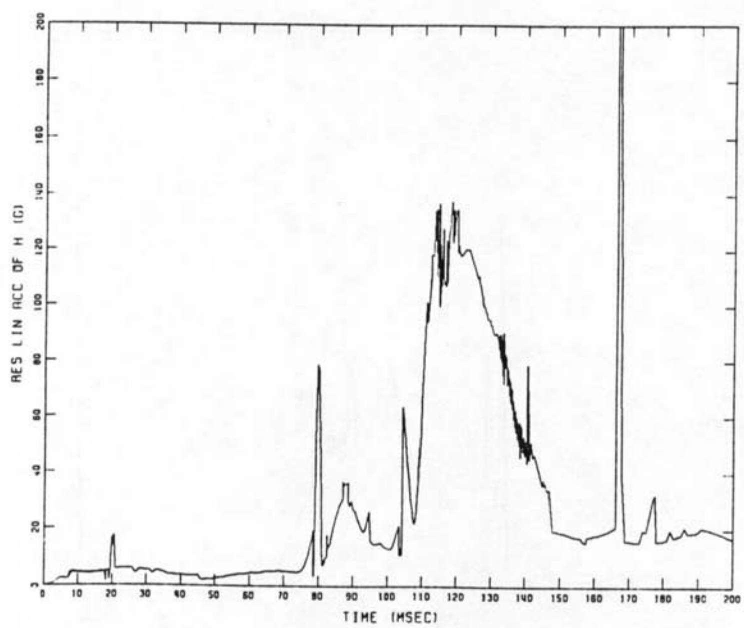


FIGURE 5

Pictorial output with N2CCG001 data

(a) CVS on a minicomputer (from reference [15])

(b) SJSATBPC on a microcomputer

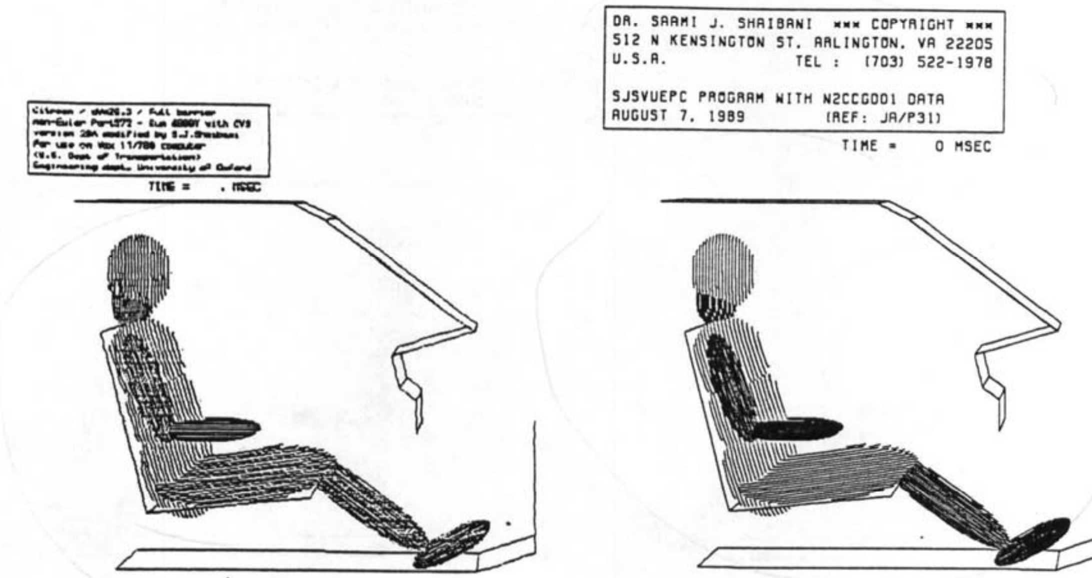


FIGURE 6

Pictorial output with E2CCG001 data

(a) CVS on a minicomputer (from reference [15])

(b) SJSATBPC on a microcomputer

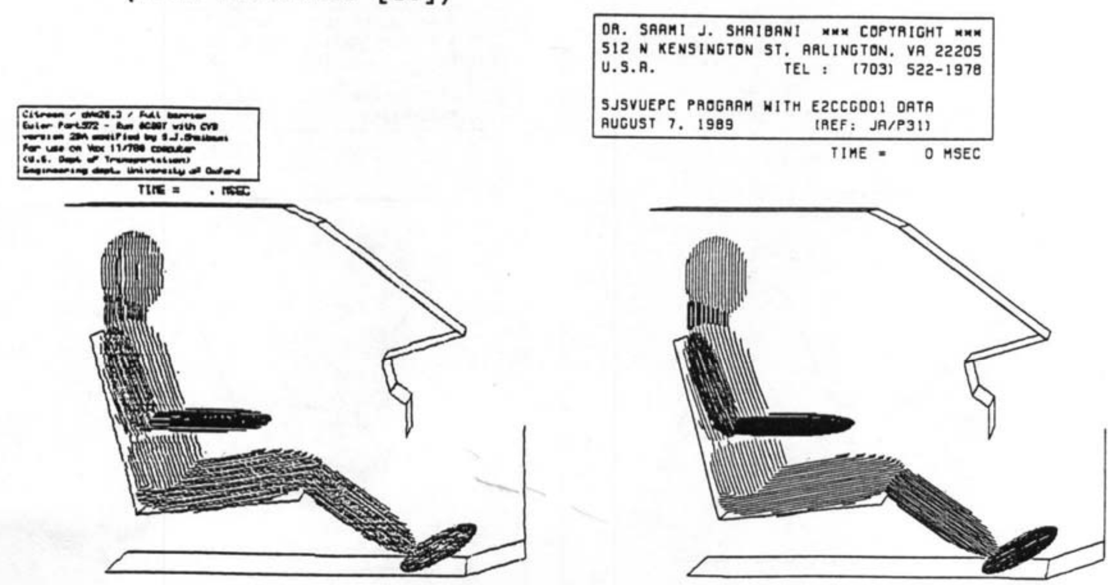
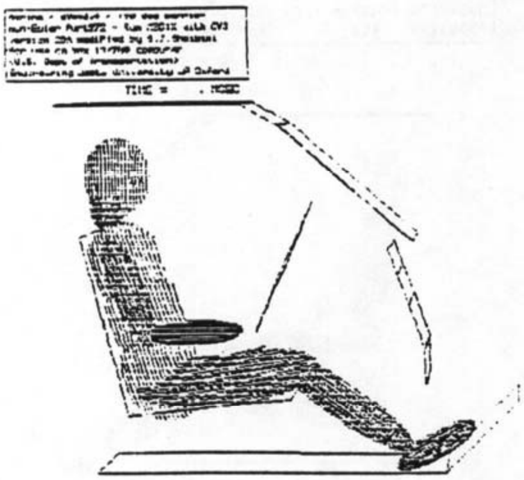


FIGURE 7

Pictorial output with N4BMS001 data

(a) CVS on a minicomputer
(from reference [16])



(b) SJSATBPC on a microcomputer

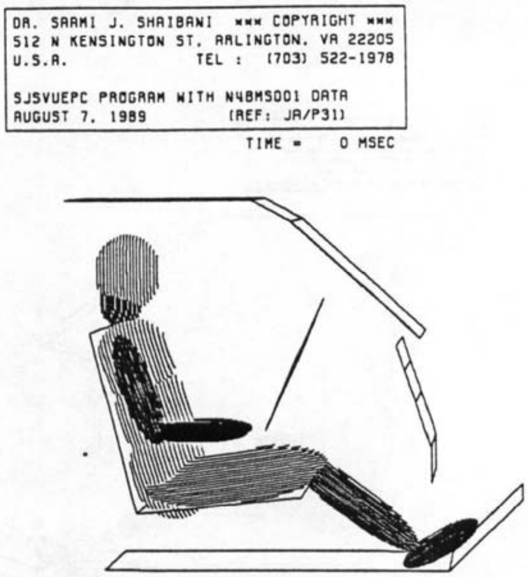
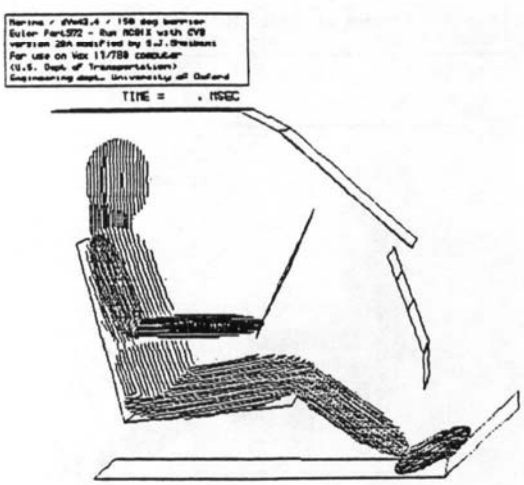


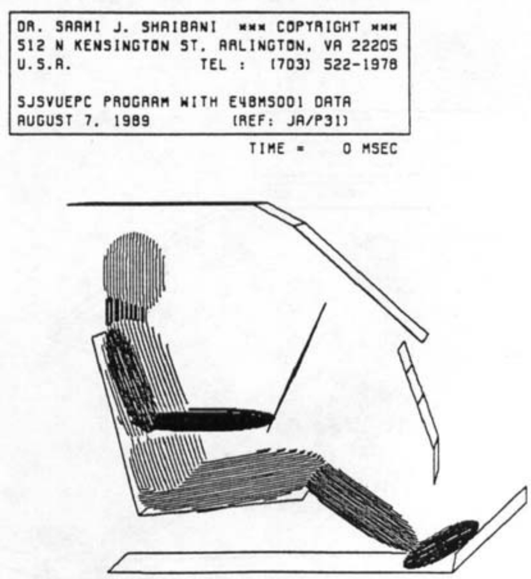
FIGURE 8

Pictorial output with E4BMS001 data

(a) CVS on a minicomputer
(from reference [16])



(b) SJSATBPC on a microcomputer



very well, and the level of agreement already seen as a function of time suggests that the correspondence would hold at other values of t.

It must be emphasized that the potential for discrepancies in the above types of comparative exercise is quite significant. This is because there was an ever-present danger of data corruptions being introduced by the media transfers, which took place over a period of several years and which involved the exchange of hundreds of lines of data between computers. This was true for each separate transfer, including : copying from hard disk to tape on a minicomputer; copying from that tape to the hard disk of another minicomputer; downloading from a minicomputer hard disk to a microcomputer hard disk, across (sometimes noisy) public telephone lines via a modem and a terminal emulator ; copying from hard disk to floppy disk on a microcomputer; and, copying from that floppy disk to the hard disk of another microcomputer.

4. Conclusions

The obvious benefits of using the SJSATBPC package in the microcomputer environment may be summarized thus :

(a) mainframe-quality results

(b) quick turnaround

(c) ease of access

(d) ready availability

(e) low cost

The rigorous validation exercises undertaken in this study clearly show how true benefit (a) is. Benefits (b) to (e) are all consequences of employing a microcomputer, which does not have the disadvantages sometimes associated with minicomputers and mainframe computers, for example : delays due to batch processing; down-time for regular maintenance, upgrading and back-up purposes; time-sharing constraints; the vagaries of computer system managers; possibility of data corruption from line noise at remote sites; surcharges or premium rates for on-line execution; and so on.

Acknowledgment

The majority of the research described in this paper was performed by the author while he was a member of staff at the University of Oxford. The author wishes to express his thanks and appreciation to his colleagues there, who made computing resources available to him and thus mitigated in a small way the damaging delays caused by economic factors beyond his control.

Appendix

Each CVS input deck may be described by an eight-character label, as follows :

$$\langle L_1 \rangle \langle A_1 \rangle \langle A_2 \rangle \langle A_3 \rangle \langle A_4 \rangle \langle A_5 \rangle \langle N_1 \rangle \langle N_2 \rangle$$

where L, A and N are alphabetic, alphanumeric and numeric characters, respectively. The definitions in Table A.1 constitute a quasi-mnemonical system that may be adopted for the values which these characters may take. The majority of the suggested values and examples in the table are self-explanatory, and the few which are not have the mnemonics given here: for #1, A denotes Alderson and L large; for #3, A, B and C denote 10, 11 and 12 (cf. hexadecimal); and, for #6, B denotes both (an airbag and a two-point belt), while C denotes complete (restraint system).

It should be noted that there is a loose correspondence between the order of the characters (Table A.1) and the order of the cards in the input deck (Table 1), as shown in Table A.2. The purpose of the system of nomenclature proposed here is to establish some consistency in the identification of the many different types of CVS input decks, both for in-house applications at one site as well as having common referencing at more than one site. An additional benefit of the system is that it will greatly facilitate the exchange of information between users of CVS, in much the same way that was achieved by the plane numbering and function numbering conventions defined during the research at the University of Oxford [11-17].

There is sufficient intentional flexibility in the scheme outlined here that even complex cases can be considered -- for example, rollover (simply put character #3 as R) or insults in the z-direction, such as those found in naval or aeronautical circumstances (again, use character #3, this time with the value Z). These latter scenarios may also require associated changes in the values of other characters, such as having character #2 represent 0.1 x acceleration instead of 0.1 x delta velocity. Clearly, the possibilities are virtually limitless and the scheme can be modified or adapted, as desired.

TABLE A.1

Nomenclature of eight-character label
for description of CVS input decks

#	meaning	suggested value	example
1	type of occupant	first letter of name	A - Sierra C - child E - Euler Part572 F - female H - Hybrid III L - 95th percentile N - non-Euler Part572 P - pedestrian S - side impact
2	magnitude of impact	0.1 x delta velocity, dv	0 - 0 < dv < 9 1 - 10 < dv < 19 2 - 20 < dv < 29 3 - 30 < dv < 39 etc
3	direction of impact	direction of clock	1, 2, 3, 4, 5, 6, 7, 8, 9, A, B & C
4	geometry of vehicle	first letter of name	(implied)
5	properties of vehicle	supplementary to #4	(eg, steering column)
6	restraint system	number of belts and/or airbag	0 - none 2 - two-point belt 3 - three-point belt A - airbag B - airbag + two-pt C - airbag + three-pt
7,8	variations	consecutive	01, 02, 03, ...

TABLE A.2

Correspondence between characters in name of CVS input deck and actual CVS input cards to which each character refers

character(s)	input cards
1st	B
2nd & 3rd	C
4th	D
5th	D & E
6th	D, E & G

References

1. McHenry, R.R. and Naab, K.N. (1966). Computer simulation of the automobile crash victim - A validation study. Calspan Corporation Report YB-2126-V-1R, July 1966 (Buffalo, NY: Calspan Corporation).

2. Segal, D.J. and McHenry, R.R. (1968). Computer simulation of the automobile crash victim - Revision No. 1. Calspan Corporation Report VJ-2492-V-1, March 1968 (Buffalo, NY: Calspan Corporation).

3. Kidd, E.A. (1970). Development of physical and analytical simulating of the automobile crash victim. Calspan Corporation Report VJ-2554-V-1, December 1970 (Buffalo, NY: Calspan Corporation).

4. Bartz, J.A. (1971). A three dimensional computer simulation of a motor vehicle crash victim. Calspan Corporation Report VJ-2978-V-1, July 1971 (Buffalo, NY: Calspan Corporation).

5. Fleck, J.T., Butler, F.E. and Vogel, S.L. (1974). An improved three-dimensional computer simulation of motor vehicle crash victims. Calspan Corporation Report ZQ-5180-L-1 (Buffalo, NY: Calspan Corporation).

6. Fleck, J.T., Butler, F.E. and Vogel, S.L. (1975). An improved three-dimensional computer simulation of crash victims - Volume 1: Engineering manual. U.S. Department of Transportation publication DOT HS 801 507, April 1975 (Washington, DC: U.S. Department of Transportation). [Available through NTIS, Springfield, VA 22161, via Accession No. PB-241 692.]

7. Fleck, J.T., Butler, F.E. and Vogel, S.L. (1975). An improved three-dimensional computer simulation of crash victims - Volume 2: Model validation. U.S. Department of Transportation publication DOT HS 801 508, April 1975 (Washington, DC: U.S. Department of Transportation). [Available through NTIS, Springfield, VA 22161, via Accession No. PB-241 693.]

8. Fleck, J.T., Butler, F.E. and Vogel, S.L. (1975). An improved three-dimensional computer simulation of crash victims - Volume 3: User's manual. U.S. Department of Transportation publication DOT HS 801 509, April 1975 (Washington, DC: U.S. Department of Transportation). [Available through NTIS, Springfield, VA 22161, via Accession No. PB-241 694.]

9. Fleck, J.T., Butler, F.E. and Vogel, S.L. (1975). An improved three-dimensional computer simulation of crash victims - Volume 4: Programmer's manual. U.S. Department of Transportation publication DOT HS 801 510, April 1975 (Washington, DC: U.S. Department of Transportation). [Available through NTIS, Springfield, VA 22161, via Accession No. PB-241 695.]

10. Fleck, J.T. and Butler, F.E. (1975). Development of an improved computer model of the human body and extremity dynamics. Armstrong Medical Research Laboratory Report AFAMRL-TR-75-11, July 1975 (Dayton, OH: Armstrong Medical Research Laboratory, Wright

Patterson Air Force Base).

11. Shaibani, S.J. (1982). A uniform input data convention for the Cal 3-D Crash Victim Simulation. Oxford University Engineering Laboratory Report No. 1419/82, July 1982 (Oxford, England: Department of Engineering Science, University of Oxford).

12. Shaibani, S.J. (1982). Application of the Cal 3-D CVS program to evaluate the equilibrium position of an Euler-jointed Alderson Part572 Oxford University Engineering Laboratory Report No. 1426/82, August 1982 (Oxford, England: Department of Engineering Science, University of Oxford).

13. Shaibani, S.J. (1982). Review of CVS work conducted at Oxford University between June 1982 and September 1982. Oxford University Engineering Laboratory Report No. 1427/82, September 1982 (Oxford, England: Department of Engineering Science, University of Oxford).

14. Shaibani, S.J. (1983). The modelling of occupant response in collisions of delta-v = 30 mph with different principal directions of force from 0 degrees to 30 degrees. Oxford University Engineering Laboratory Report No. 1456/83, February 1983 (Oxford, England: Department of Engineering Science, University of Oxford).

15. Shaibani, S.J. & Digges, K.H. (1983). Analytical reconstructions of front seat passenger response in a road accident. Oxford University Engineering Laboratory Report No. 1457/83, March 1983 (Oxford, England: Department of Engineering Science, University of Oxford).

16. Digges, K.H. & Shaibani, S.J. (1983). Analytical reconstructions of driver response in a road accident. Oxford University Engineering Laboratory Report No. 1458/83, April 1983 (Oxford, England: Department of Engineering Science, University of Oxford).

17. Shaibani, S.J. (1983). The reconstruction of vehicle occupant response in road traffic accidents. Film made at Computing Teaching Centre, University of Oxford, England.

18. Maltha, J. and Wismans, J. (1980). Madymo - Crash Victim Simulations - A computerized research and design tool. Vth Int. IRCOBI Conf. on the Biomechanics of Impacts, Birmingham, England (Bron, France: IRCOBI).

19. Leetch, B.D. and Bowman, W.L. (1981). Articulated Total Body (ATB) VIEW package software report - Volume 1. Armstrong Medical Research Laboratory Report AFAMRL-TR-81-111, October 1981 (Dayton, OH: Armstrong Medical Research Laboratory, Wright Patterson Air Force Base).

20. Leetch, B.D. and Bowman, W.L. (1981). Articulated Total Body (ATB) VIEW package software report - Volume 2. Armstrong Medical Research Laboratory Report AFAMRL-TR-81-111, October 1981 (Dayton, OH: Armstrong Medical Research Laboratory, Wright Patterson Air Force Base).

DISCUSSION

PAPER: The SJSATBPC Package: Mainframe Quality Results with Crash Victim Simulation in the Microcomputer Environment

SPEAKER: Saami J. Shaibani

Question: John Tomassoni, Jetech

I was just curious about the fact that you used a half-sine pulse. Did you by any chance exercise any other pulses to find out is they had any effect?

Answer: No, in this particular reconstruction, we didn't because it was such a major event; a delta V of 45 mph, that we were trying to understand what the general injuries were. Now, I did mention that there were three injuries. There was a chest injury and that was an AIS of 4 and with the value of CSI that the program gave that seemed to give fairly reasonable agreement. The second injury was an AIS 3. Now, the very unusual injury that we saw here was a dislocated left hip. I'm told that dislocation without some kind of fracture is very unusual within the automotive environment. We believe that that occurred because the rotation was so severe that the hip popped before any significant longitudinal loading along the femur could take place. Now, when you get major events like this taking place, to come back to your question, using different pulses becomes a very fine point. This car was mangled beyond recognition, 45 delta V, something like a Ford Escort. We just had no idea. I can't find any experimental data that would give me a reasonable crash pulse for that. So, as a first effort, we tried a half-sine wave and the injuries matched pretty consistently. As far as I'm concerned, that really is the bottom line. It would be nice to have some sort of refinement but it's almost like having too much of a good thing. If a half-sine wave does the job then we have to accept that in the first instance.

Q. Richard Morgan, NHTSA

How should we refer to this CVS program, for shorthand? Your notation is sort of complicated.

A. I've already had comments from Dr. Eppinger as to the suitability of the acronym. Bear in mind that this is a fairly informal environment. I wouldn't expect people to get their tongues around such an awkward expression. Feel free to use any generic term that you want to use. I don't lay any specific claim for this. I made a lot of improvements and tidied it up a bit but a lot of this work was really set in motion in the mid-seventies. I just brought it to fruition within the PC environment. So I'm happy to have it called CVS on the PC and be done with it. I prefer CVS to ATB, by the way, but that's just a personal quirk of mine.